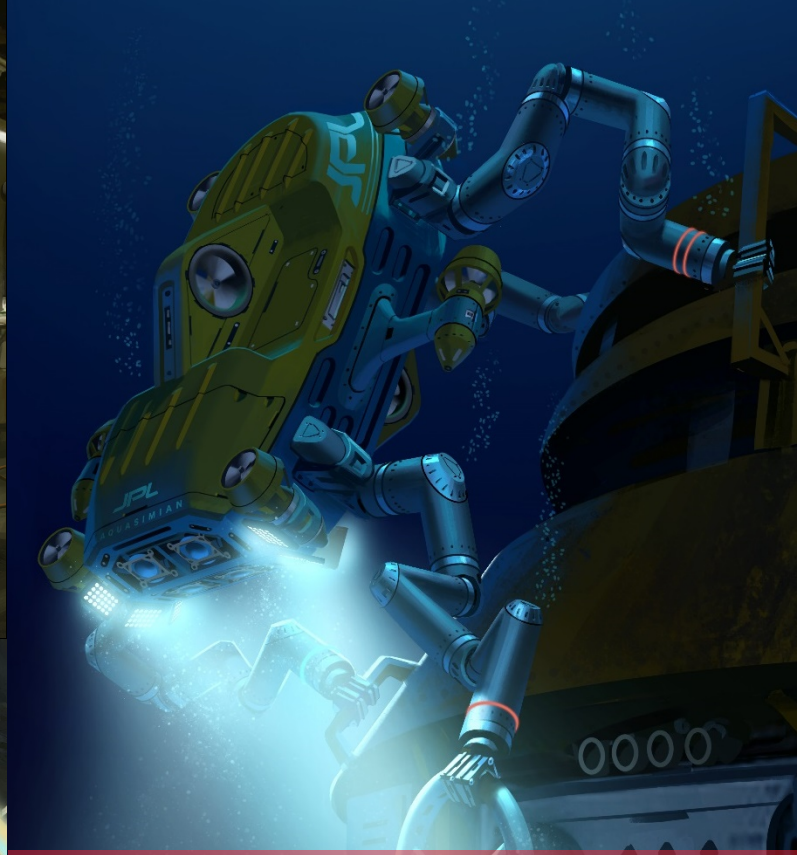


From Outer Space to the Assembly Line

Presented by Chris Yahnker

Mobility and Robotic Systems Section,
Autonomous Systems Division

February 6, 2019

Jet Propulsion Laboratory
California Institute of Technology

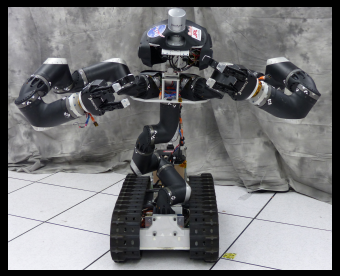
JPL is part of NASA and Caltech

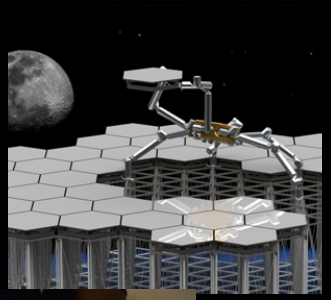
- Federally-funded (NASA-owned) Research and Development Center (FFRDC)
- University Operated (Caltech)
- 6,000+ Employees

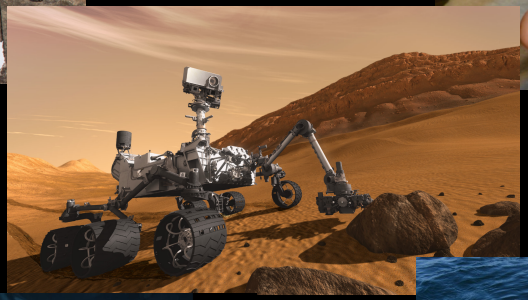
- 167 Acres (includes 12 acres leased for parking)
- Located ~10min from Caltech in Pasadena
- 673,000 Net Square Feet of Office Space
- 906,000 Net Square Feet of Non-Office Space (e.g., Labs)

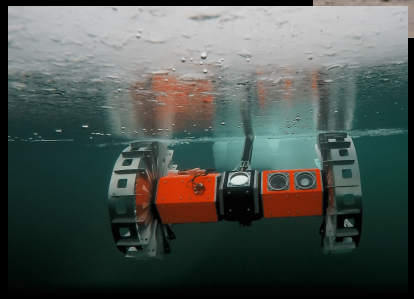
Robots on a Mission

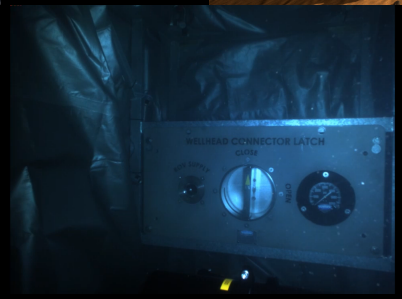
Robot Platforms for all Environments





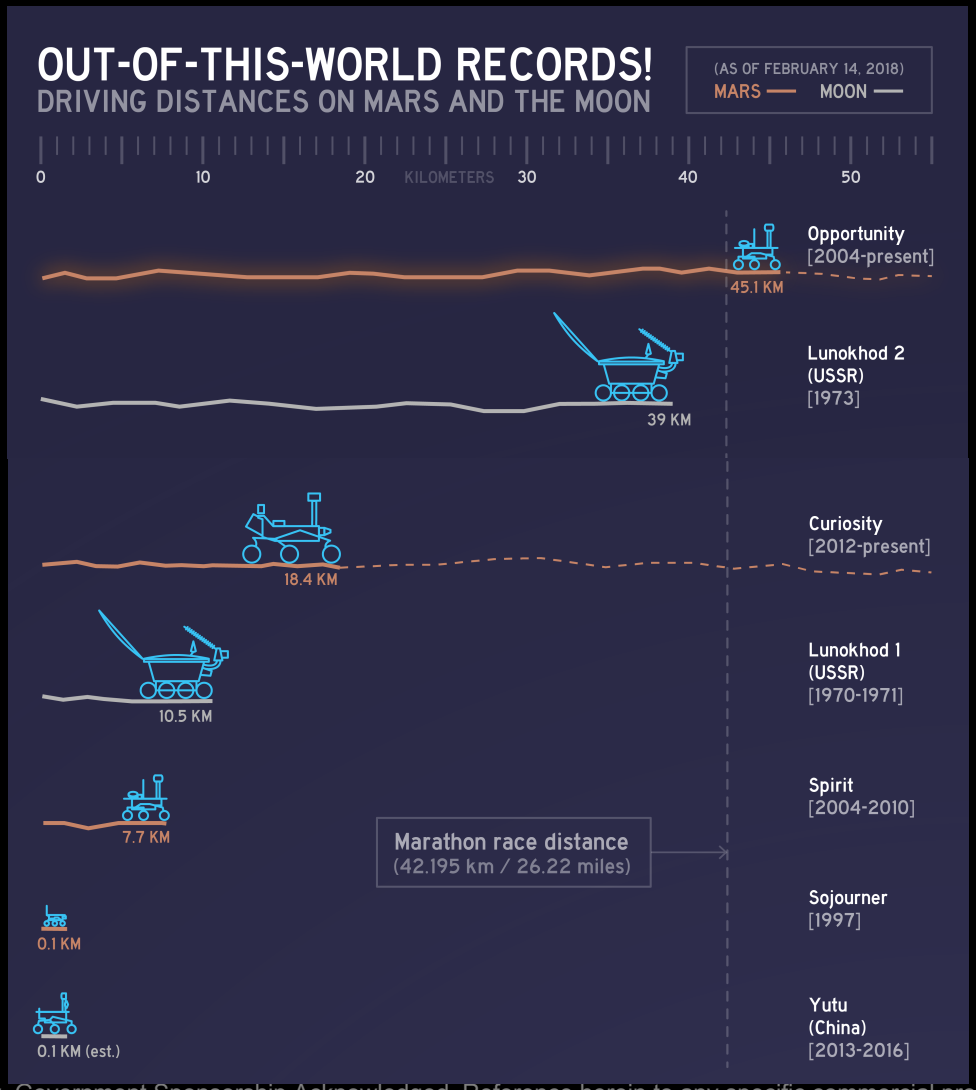






JPL Develops High-Reliability Robots

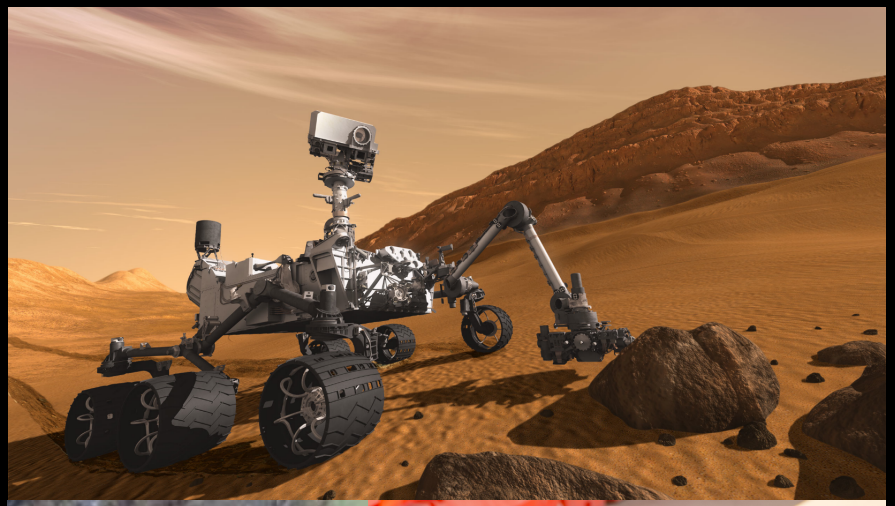
And that takes engineering the *complete* system

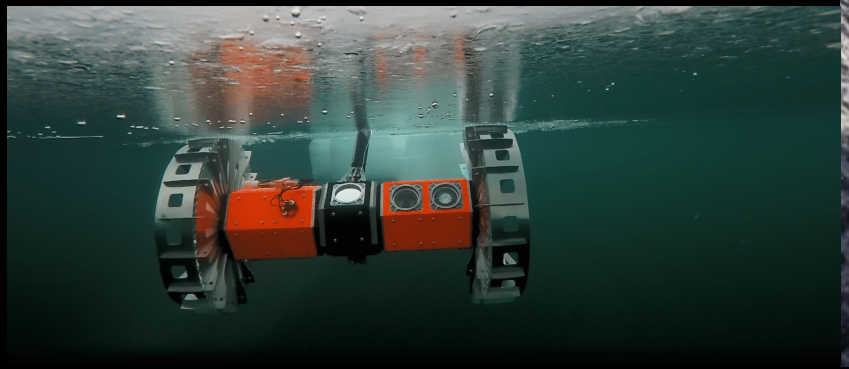


© 2019 California Institute of Technology. Government Sponsorship Acknowledged.

Key Robotic System Technologies

- Robot systems' software architecture and implementation
- Machine vision and sensor processing algorithms
- Mobility and manipulation control algorithms
- Advanced electro-mechanical systems development
- Integrated simulation of landing and mobility
- Human to robot interfaces
- Robot design, integration, test, and operation

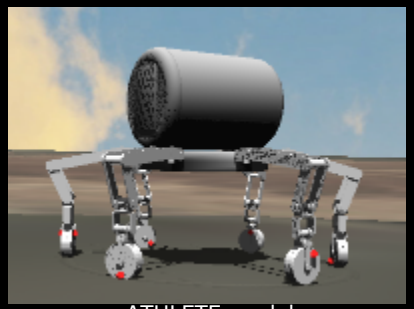




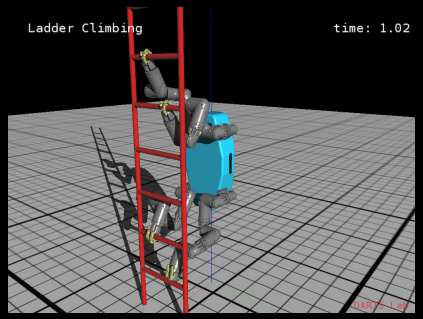
© 2019 California Institute of Technology. Government Sponsorship Acknowledged

Physics-Based Simulation

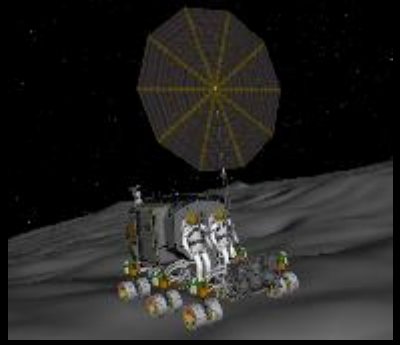
- High-fidelity physics-based modeling and simulation
  - DARTS/DSHELL, M3TK
- Includes hardware-in-the-loop capabilities
- Features:
  - Large high-resolution terrain models
  - Contact dynamics and complex mechanisms
  - Terra-mechanics, aerial, surface and sub-surface models
  - Incorporates thermal, power, communication and other dynamics
  - Parametric analysis and Monte-Carlo simulations
  - GPU-based techniques for computation



ATHLETE model

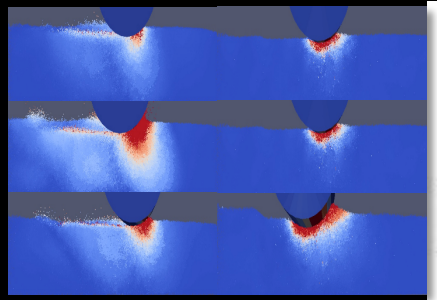


RoboSimian climbing

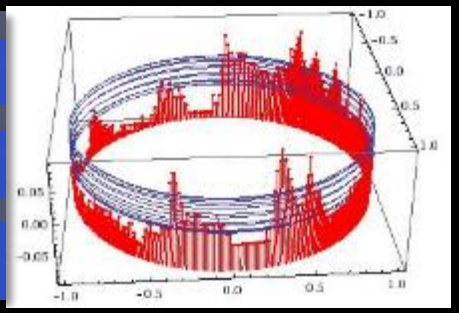


Simulated Lunar Electric Rover model

Aerobot model



Granular media model of wheel-soil interaction

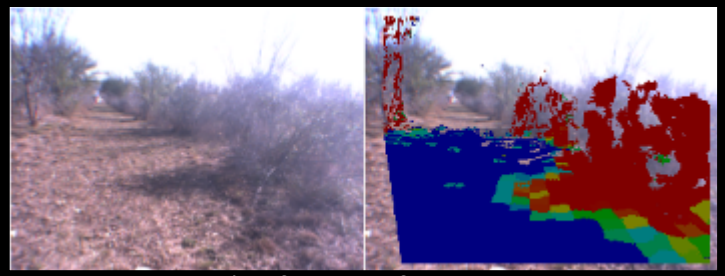


Solar illumination at the South Pole of the Moon

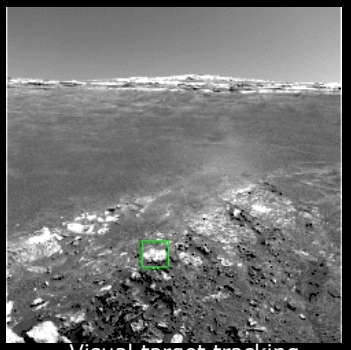
Sensing/Perception

Develop models from sensors in real-time

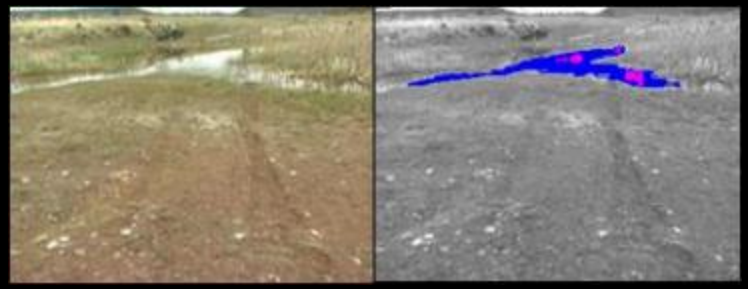
- Stereo-vision
- Environment classification from texture
- Target tracking
- Structure from motion
- Aerial Surveillance
- Object recognition
- Activity recognition
- Shape from shadow/shading
- Odometry
- Force/position/self sensing
- Advanced sensors
  - Spectrometers, imagers
  - *In-situ* Chemistry



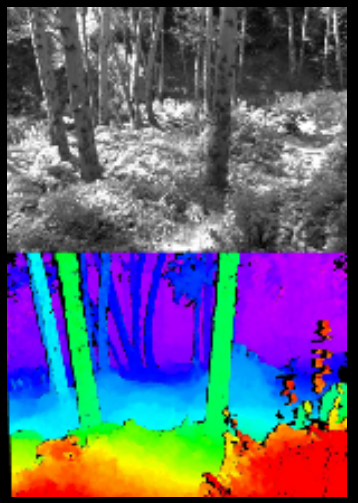
Terrain classification: safe traverse region



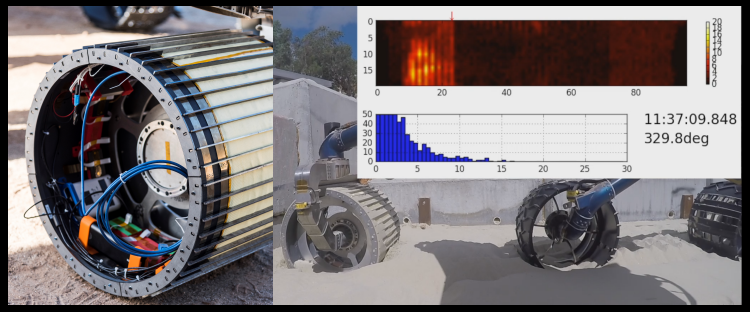
Visual target tracking



Terrain classification: water detection



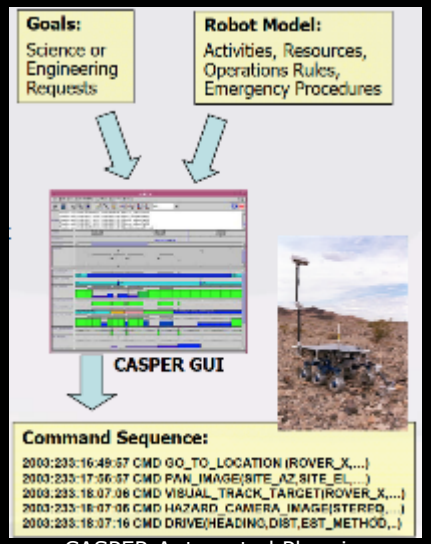
Real-time stereovision



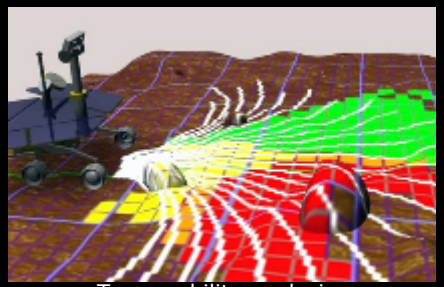
Terrain classification: Tactile Wheel for touch and "taste"

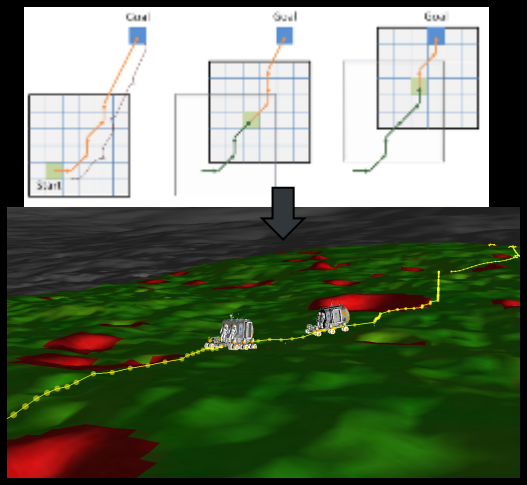
Mobility Planning and Execution

- Map building
- Navigation
- Traversability
- Path planning
- Optimal resource utilization
- Machine Learning for situational awareness
- On-board science
  - Respond to dynamic opportunities – autonomously recognize a science event or target
  - Prioritize data for down-link – send the most interesting information first

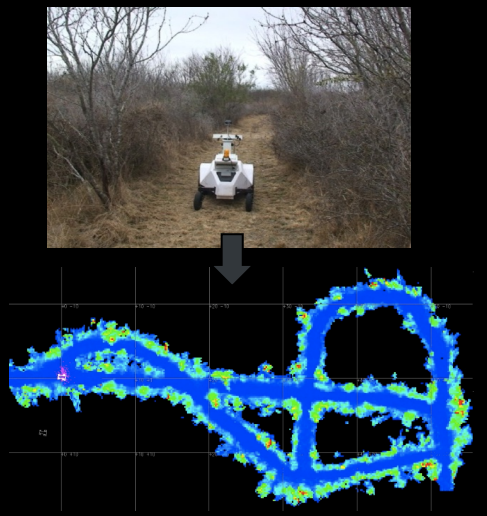


CASPER Automated Planning System


Traversability analysis

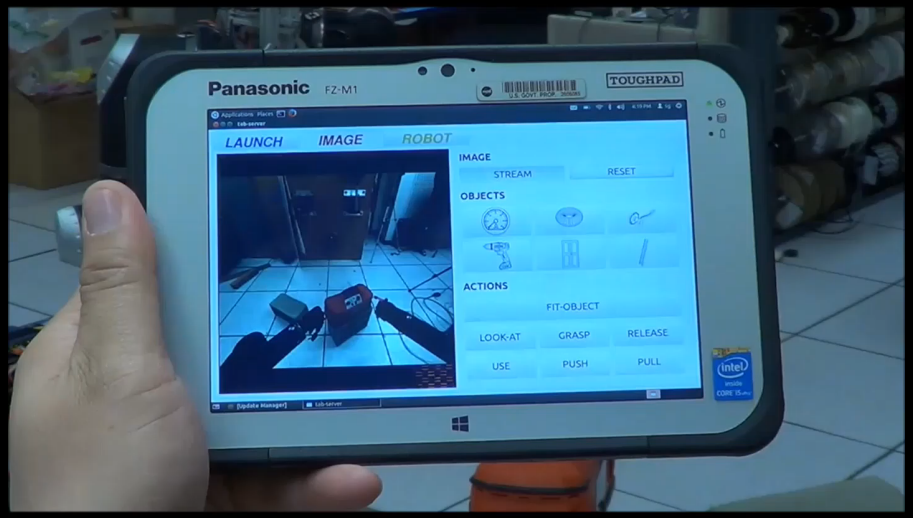


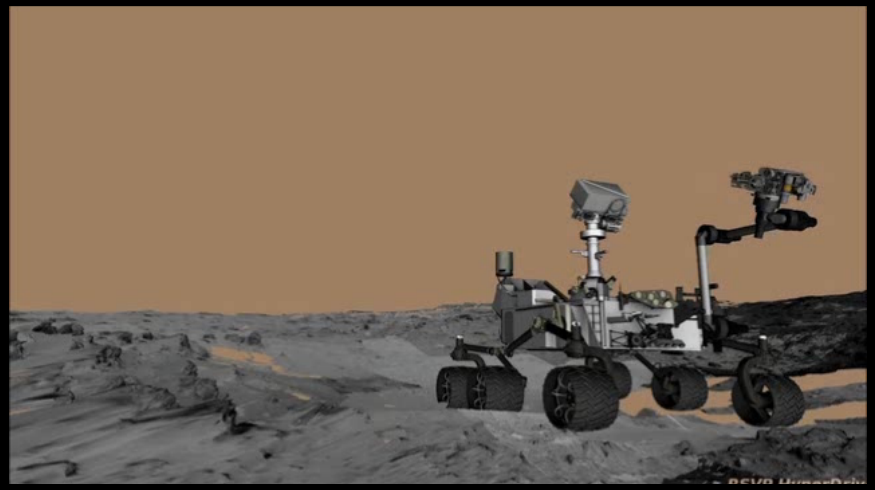
Path planning to avoid hazards

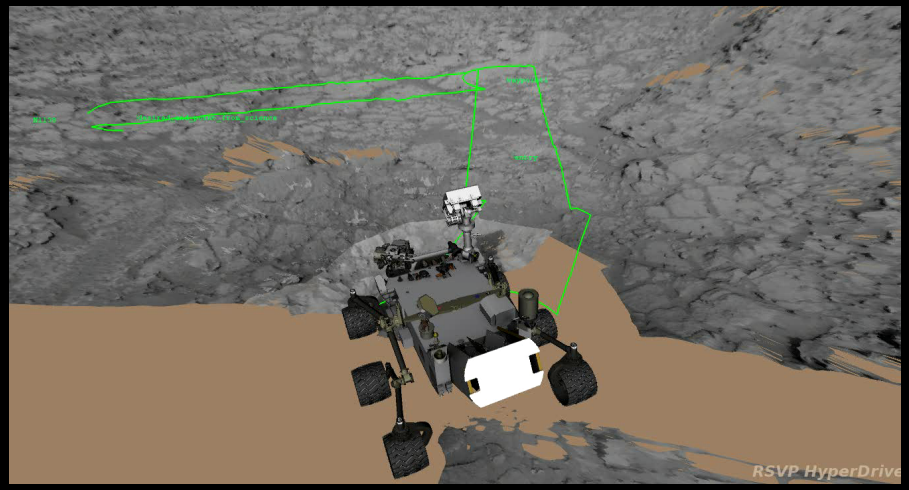

Simultaneous Localization and Mapping

Operator Interfaces

- Ranges from simple/quick to exhaustive
- Command sequence generation & scripting
- Operations simulation & rehearse
- Safety verification
- Engineering data visualization
- Virtual or augmented reality







System Design for Robustness and Testing

Navy ASV and AUV Example

- JPL under contract since 2004 with US Navy, OSD, DARPA, and commercial partners to transition NASA flight-derived intelligent autonomy technology to unmanned surface and underwater boats
- Develop and demonstrate advanced behaviors and capabilities for intelligent US Navy mission-level autonomous control and long duration operation of ASVs & AUVs operating under sparse advisory control and with onboard self-contained sensing and decision making.
- Demonstrated “Full-Scale” autonomy:
  - Sensor systems and situational awareness
  - Tactical planning and control
    - Hazard avoidance, COLREGS compliance
    - Search, intercept & inspect, track & trail
  - Mission planning/replanning
    - Adaptation to health, resource usage, mission progress
    - Multi-vehicle coordination
  - Fault-aware operations
  - Sparse operator input

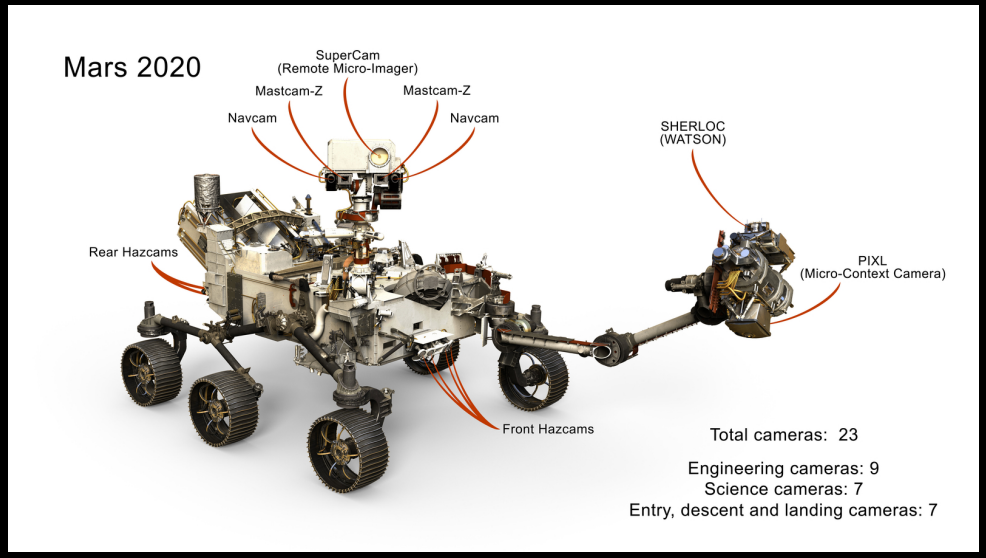
The future of robotics

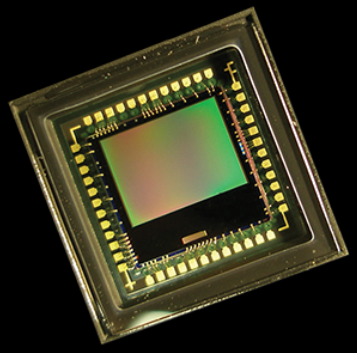
Where are we going and what are we doing; what do we need to get there?

- Integrated physical systems
  - Print your robot
- Innervated robots
  - Giving robots all of the channels
- On-board decision engines
  - Robots making useful decisions even with limited processing/memory
- System design tools
  - Multi-Physics meets CAD meets Hardware/Software Emulator

Technology Transfers

CMOS Sensors – Need small, low mass, high resolution cameras for space applications





CMOS Chip

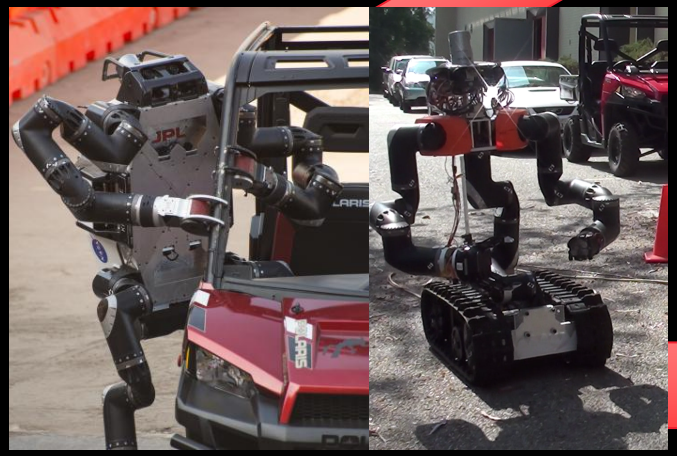
Consumer Products & Cell Phone Cameras

Images courtesy of NASA and GoPro

Technology Transfers

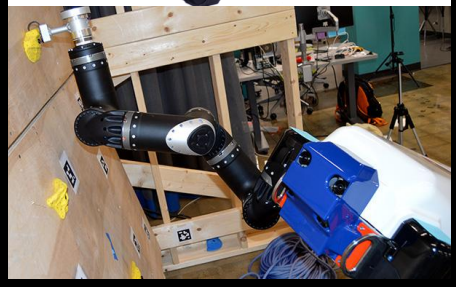
RoboSimian & Surrogate – High Dexterity Robotic Platforms

ARL / General Dynamics
RoboSimian & RoMan



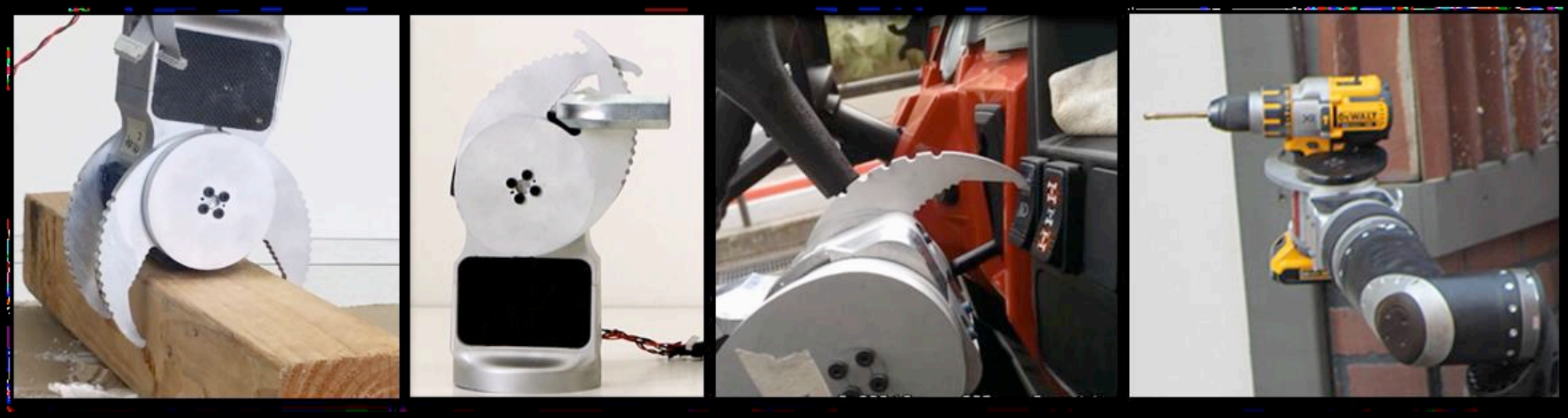
JPL
RoboSimian & Surrogate

Motiv Robotics
RoboSimian & RoboMantis



Technology Transfers

RoboSimian Cam Hand – Robust, highly configurable end effector for rescue robots, unexploded ordinance disposal, construction, and other tasks



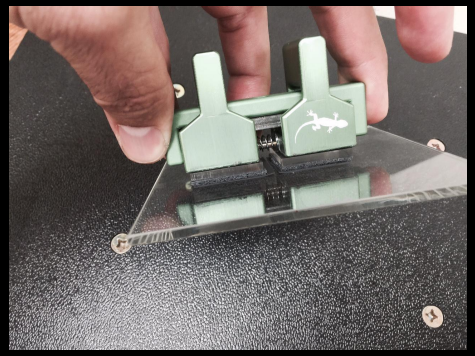
Motiv robotics gripper

Images courtesy of NASA/JPL and Motiv robotics

Technology Transfers

Gecko Gripper – Need a way to grab onto smooth surfaces quickly & reliably

Inspiration



Prototype

Test

Space Application
(ISS)

Commercialization

Images courtesy of NASA/JPL and On Robot

More information

- NASA's Technology Transfer (T2) Program
  - spinoff.nasa.gov
- Office of Technology Transfer at JPL
  - nsta.jpl.nasa.gov/dep-technology-transfer
- JPL Commercial Program Office
  - https://nsta.jpl.nasa.gov/dep-commercial

Jet Propulsion Laboratory
California Institute of Technology